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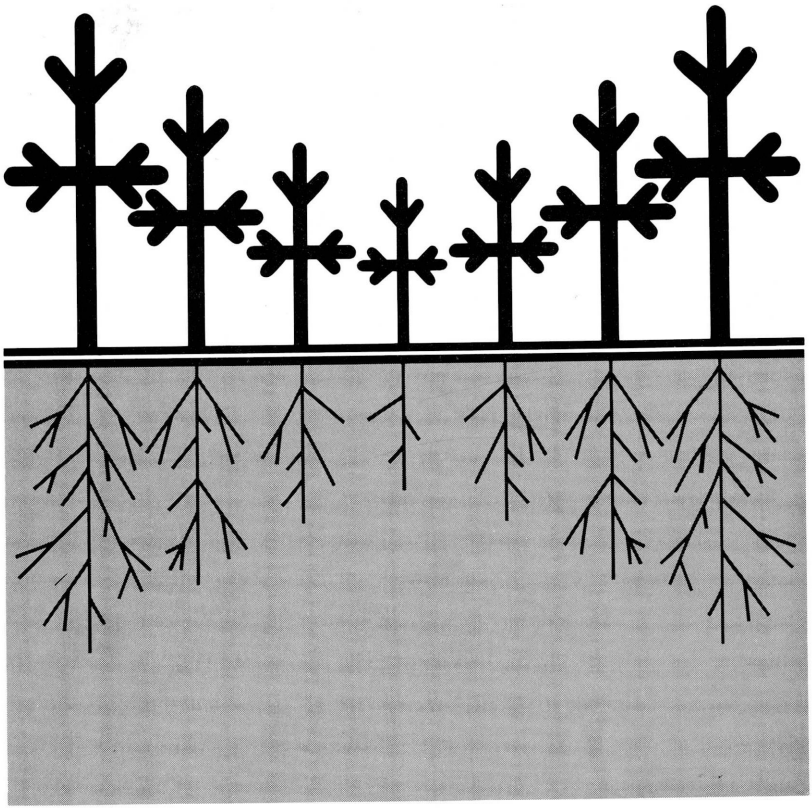
Management Guide To Phytophthora Root Rot in Bareroot Conifer Nurseries of the Pacific Northwest



Management Guide To Phytophthora Root Rot in Bareroot Conifer Nurseries of the Pacific Northwest

By

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Preface

This USDA-Forest Service publication was prepared to help forest nursery personnel plan and implement the most effective and timely actions for managing Phytophthora root rot in their nurseries.

Additional copies of this publication can be obtained from Forest Pest Management, USDA-Forest Service, Pacific Northwest Region, P.O. Box 3623, Portland, OR 97208.

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A Guide To Management of Phytophthora Root Rot in Bareroot Conifer Nurseries of the Pacific Northwest

Introduction

Phytophthora root rot of conifer seedlings is a common problem in Pacific Northwest bareroot forest nurseries. In many situations, this disease can cause extensive mortality or cull. Damage can be limited or prevented on good nursery soils by proper cultural practices. Under some circumstances, the use of fungicides and fumigants for treating Phytophthora root rot is warranted. In this pamphlet, guidelines are outlined for managing Phytophthora root rot on field-grown seedlings.

Preceeding the guidelines are sections on symptomology of the disease, biology of *Phytophthora* spp. affecting conifers, and a discussion of cultural and chemical control.

Identification of Phytophthora Root Rot in the Nursery

1. Seedlings for 1-0 or 2-0.

First Year. Symptoms usually are not seen during the first year of seedling growth. Root symptoms, if present, are normally confined to the lower one-third of the root system. Infected root tissue has characteristic reddish-brown discoloration (see description of root discoloration under *Second Year*, below). Usually no above-ground symptoms occur. Infected seedlings most often are confined to low-lying, poorly drained areas, but may be present over large areas with heavy clay soils.

Reddish-brown discoloration of root cambium due to infection by *Phytophthora* spp. Note the distinct demarcation between live and dead tissue and the lack of fine roots in the discolored part of the root.

Second Year. Above-ground symptoms generally appear in the spring of the second year. They consist of chlorosis, stunting, wilting, needle browning, and mortality. Stunting or "bottle brush" appearance is due to delayed budbreak and poor branch and needle elongation. A progression of foliage symptoms is seen; from chlorosis of the current year's needles and stunting early in the growing season to wilting and mortality later in the season. If symptomatic seedlings are uprooted, cambium discoloration, root decay, and absence of roots will be seen on the root system. If cortical tissue (bark) is carefully removed from infected roots by scraping with a knife, discoloration of cambium will be evident. Discoloration ranges from

Above-ground appearance of infected (right) and healthy (left) Douglas-fir seedlings. Infected seedling is chlorotic and stunted.

Phytophthora root rot pocket in Douglas-fir seedling beds. Standing water in tractor paths indicates poor soil drainage.

red to dark-brown. The border between healthy and infected tissue usually is distinctly delineated but sometimes is irregular, having fine streaks of discoloration. The location and amount of discoloration and root loss depends on the severity of infection. If seedlings are lightly infected, only the tips of some roots are discolored and dead. On severely infected seedlings, the entire root system may be dead, most secondary roots may be missing, and the margin between healthy and infected tissue will be at or above the root collar. Symptomatic seedlings most frequently are found where soil is poorly drained (low spots, bed ends, drainage contours, high water table soils, heavy clay soils) or where flooding has occurred.

2. Transplants.

Above-ground symptoms generally are not seen until late winter or early spring if seedlings are transplanted in the fall. If they are transplanted in the spring, symptoms will appear in late spring or early summer. Severely infected seedlings will have stubby lateral and tap roots which lack fine roots. Occasionally, new shoot growth will begin, only to wilt quickly and die. Foliage and cambium appearance of infected transplants are as described for 2-0's under *Second Year*. The time of symptom appearance and its distribution in a field will depend on whether seedlings were infected prior to or after transplanting. Symptoms will appear earlier in those seedlings infected prior to transplanting. Infected seedlings will be scattered throughout the field, although more concentrated in wet areas. Symptoms on trees infected after transplanting appear somewhat later. These infected seedlings are usually confined to poorly drained areas of the field. In either case, damage can become significant, particularly if the soil remains saturated into early summer. In Pacific Northwest nurseries, transplant beds typically have had the greatest amount of root rot.

Biology of Phytophthora Species Affecting Conifers

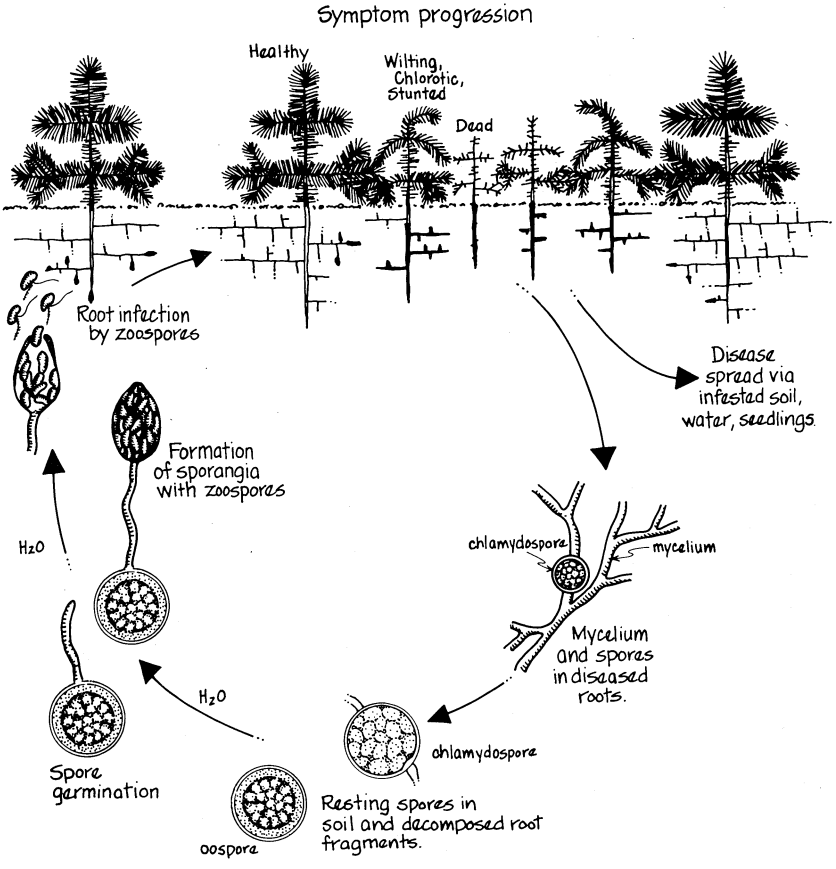
Several species of *Phytophthora* cause disease on conifer seedlings in nurseries: *P. cactorum, P. cryptogea, P. dreschleri, P. pseudotsugae,* two different groups of *P. megasperma* and, to a lesser extent, *P. cinnamoni* (*11, 12, 13, 14, 17*). Typically, two or three species are present in any one nursery. Seedling roots are infected by motile zoospores (asexual swimming spores) that are attracted to root tips and wounds (*7*). Zoospores germinate and hyphae penetrate the root epidermis and grow within phloem tissue. Infected tissue is killed. Growth of the fungus usually is restricted to the phloem below the root collar since above-ground stem tissue quickly dries out following root mortality and cannot support the fungus. Zoospores can move short distances in saturated soil (*6*) or longer distances in the overland flow of water (*18*).

Sexual spores, oospores, are formed in killed seedling tissue by some *Phytophthora* species. Their role in the infection process is not known, but probably is similar to chlamydospores. Chlamydospores, thick-walled, asexual "resting spores", are formed by some species and can withstand relatively dry conditions, thus enabling the fungus to survive throughout the summer when soil temperature is high and moisture is low (*19*). Presumably both oospores and chlamydospores can produce zoospores under conditions of abundant moisture and the presence of susceptible host roots. Chlamydospores and oospores are moved in soil on seedling roots, equipment, vehicles, etc.

Infection of roots generally occurs when soil moisture is sufficient for zoospore production and movement. In Pacific Northwest nurseries, these conditions exist from fall, after frequent rains begin, through early to mid-summer when precipitation tapers off and nurseries reduce irrigation. In the winter, when the ground is frozen or soil temperatures are low, activity of *Phytophthora* probably is quite low and little or no new infection occurs.

When soil moisture is reduced, either through drainage or during dry times of the year, progression of infection declines and new roots may be regenerated above diseased parts of the root system. If enough roots are regenerated and do not subsequently become infected, seedlings will survive and grow vigorously. However, moderately to severely infected seedlings may not recover adequately to make packing standards. Survival of lightly infected seedlings is good following outplanting, although *Phytophthora* remains viable for at least two years and can be recovered from old infected roots (*14*).

Life cycle of *Phytophthora* spp on conifer seedlings.



Cultural Control

Almost all cultural manipulations for reducing root rot involve providing good soil drainage in order to create an unsuitable environment for the proliferation of *Phytophthora*. If possible, nurseries should be located on light rather than heavy soils. Nurseries having heavy clay soils can improve drainage several ways: sub-surface drainage systems; ditch systems to drain surface water; providing slope to fields so that water drains towards roads; subsoiling to break up hardpans; and elevation of beds.

Installation of sub-surface drainage system in a bareroot conifer nursery.

If portions of a nursery or parts of a field cannot be adequately drained, then *Phytophthora*-susceptible seedlings should not be sown or transplanted in those areas. Use of chronic wet spots will result in unsalable seedlings year after year.

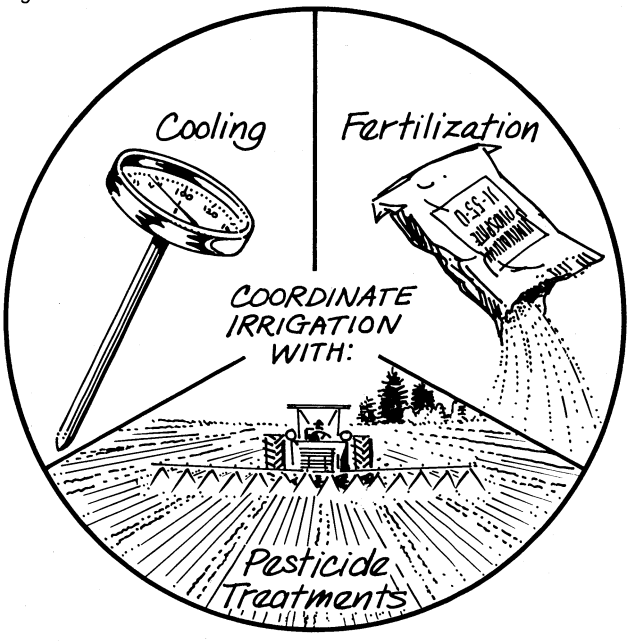
Irrigation practices can be tailored somewhat to avoid constantly saturated soils. Applications of water for cooling, frost protection, fertilization, and pesticide treatments should be timed to correspond with routine irrigation. Over-irrigation and alternating drying and saturating of soils should be avoided, particularly in areas known to be infested or when transplanting seedlings which were previously infected in seed beds.

Resistant or tolerant tree species can be used in high-risk areas (areas where *Phytophthora* was present in the previous crop, low or poorly drained spots, or areas prone to flooding). Pathogenicity trials and nursery observations have led to the following categorization of species (*10, 14, 17,* [1/]).

1) *Resistant: western redcedar.*
2) *Tolerant: hardwoods, pine, spruce, larch, incense cedar.*
3) *Highly susceptible: western and mountain hemlock, Douglas-fir, true fir.*

[1/] Unpublished data. S.J. Cooley and P.B. Hamm. USDA-Forest Service, PNW Region, Portland, OR.

Coordinate routine irrigation with other water uses to minimize high soil moisture.



Several cultural practices can reduce levels of *Phytophthora* in the soil. Large patches of diseased seedlings should be rogued at lifting to ensure that inoculum (root and stem tissue containing viable *Phytophthora* spores and mycelium) which could infect the next crop is removed from the soil. Rogued seedlings and packing house culls should not be returned to fields as organic matter or mulch since chlamydospores or oospores can survive in seedling tissues. Culls can be burned or removed from the nursery site. If culls are used as land fill at the nursery, all drainage from the fill should be away from the nursery beds or irrigation source. Use of composted cull fragments as soil amendments is risky as well; *Pythium,* a related fungus, has been recovered from cull pieces composted for over one year. [2/]

Movement of stock between nurseries should be minimized. Incoming stock may be infected with *Phytophthora,* resulting in contamination of a "clean" nursery or a "clean" field. Furthermore, additional *Phytophthora* species, not present previously, may be introduced on incoming stock.

See the following guidelines for timing of specific cultural activities.

Chemical Control

1. Fumigants.

The benefit derived from pre-plant fumigation for Phytophthora root rot control is unclear. The fumigants methyl bromide-chloropicrin, metam-sodium (Vapam®, Stauffer) and dazomet (Mylone®, Stauffer; Basamid-

[2/] Unpublished data. S.J. Cooley. USDA-Forest Service, PNW Region, Portland, OR.

Granular®, BASF) can significantly reduce soil populations of *Phytophthora* spp. and *Pythium* spp. [3/]. However, diseases caused by these fungi can and do occur in seedlings sown in fumigated soil due to either incomplete killing of spores by the fumigant or reintroduction of *Phytophthora* in water or soil. In adequately drained fields, disease incidence in nonfumigated soil may be no greater than that in fumigated soil.

Fumigation of nursery soil with methyl bromide-chloropicrin to control soil-borne pathogens.

2. Fungicides.

Several fungicides are registered for use against Phytophthora root rot on conifers and/or woody ornamentals: ethazole (Truban®, Mallinckrodt), ethazole-methyl thiophanate (Banrot®, Mallinckrodt), propamocarb hydrochloride (Banol®, Tuco), fenaminosulf (Lesan®, Mobay; Dexon®, Bayer-discontinued), metalaxyl (Subdue®, Ciba-Geigy; Ridomil®, Ciba Geigy), and phosethyl Al (Aliette®, Rhone-Poulenc). Phosethyl Al and metalaxyl are relatively new fungicides with systemic properties. The other fungicides listed are not systemic or, as with Banrot, the component active against *Phytophthora* and *Pythium* is not systemic.

Although most of these fungicides have been used with success on nonconifer crops or against other organisms (e.g., *Pythium* spp.), only metalaxyl has been extensively tested in the field on conifers and been shown to be effective (*3, 5, 9*).

Metalaxyl is marketed by Ciba-Geigy under the trade name of Subdue® (for ornamentals, conifers, and turf), Ridomil® (for agricultural crops and conifers) and Apron® (for seed treatment). Application of metalaxyl to

[3/] Personal communication, F.D. McElroy, Peninsulab, Kingston, WA and Unpublished data, P.B. Hamm and E.M. Hansen, Oregon State University, Corvallis, OR.

Phytophthora-infected seedlings has been shown to reduce mortality and severity of root rot (*3, 9*). It is systemic and can be applied to the soil as a liquid (2E) or granule (5G). Once in the soil, it is taken up by the roots. Following treatments, progression of the fungus through the root system is halted. However, *Phytophthora* will remain viable in roots and can be readily recovered (*9*). A reduction in *Phytophthora* activity occurs in treated soil (*3, 9*). Metalaxyl inhibits sporangium, oospore, and chlamydospore formation and, to a lesser extent, mycelial growth and chlamydospore germination (*2, 4, 8*). It has little or no effect on non-Pythiaceous fungi. Mycorrhizae development is not adversely affected (*16*).

Metalaxyl must be used with discretion, since there is evidence that naturally occurring tolerant strains of *Phytophthora* exist, and may become predominant with repeated, frequent use of metalaxyl (*15*). In addition, recently published work shows that the effectiveness of the material can decrease with each application due to microbical degradation (*1*). The presence of *Phytophthora* in symptomatic seedlings should be confirmed by a pathologist prior to treatment to avoid unnecessary use and expense. Careful observation of seedlings (particularly root systems) in high-risk areas throughout the year will guarantee early recognition and more effective disease control.

One well-timed treatment of metalaxyl per year appears to adequately control progression of root rot. Although further reduction in root rot is seen with multiple treatments, the reduction may not be enough to warrant additional applications (*9*). Maximum benefit will be gained from treating seedlings in the spring or fall when roots are active and can take up the fungicide. Temperatures in spring and fall are relatively cool, so that the fungicide is retained by the plant for a longer period. Treatments probably will be most effective if seedlings are treated before infection occurs or early in the infection process when only root tips are infected and no foliar symptoms are seen (*3*). Preventative treatment should be made only on seedlings in high-risk areas.

See the following guidelines for timing of specific chemical treatments. Testing of new materials will be ongoing and amendments to this publication will be made when appropriate. The pesticide precautionary statement at the back of the publication should be reviewed before use of fumigants or fungicides.

3. Water Chlorination.

In some instances, *Phytophthora* can enter the nursery in the irrigation water due to run off into the system from other agricultural sites. Water can be checked for presence of *Phytophthora* propagules. If water is contaminated, use of other water sources may be possible for some nurseries. If no other sources exist, water can be chlorinated prior to entering irrigation lines. Various types of chlorination systems are available and can be adapted to individual nursery situations. Some types of water sources would be much more likely to become contaminated with *Phytophthora* than others; for example, well water and municipal water are apt to be *Phytophthora*-free while water from agricultural districts and canal systems can easily become contaminated.

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Pesticide Precautionary Statement

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

Guidelines for Management of Phytophthora Root Rot

PRIOR TO SOWING

Chemical

- Fumigation (e.g. metam-sodium, dazomet, or methyl bromide-chloropicrin) may be helpful in nurseries, particularly where *Phytophthora* was present in previous crop.

Cultural

- Ensure adequate drainage by ditching; tiling.
- Subsoil to remove or break up hardpans.
- Provide some slope to actual seedbed areas.
- Raise seedbeds prior to sowing.
- Sow resistant or tolerant tree species [1/] in high-risk areas [2/].
- Avoid sowing in chronically wet areas or in drainages.
- Do not plant bed ends which are lower than the road.
- Clean equipment between nursery areas and between nurseries.

FIRST YEAR

Chemical

- In fall or winter, apply metalaxyl if symptoms appear [3/]. In winter, soil may be too wet to move spray equipment onto; if so, apply fungicide as soon as soil dries sufficiently.

Cultural

- Avoid causing excess soil moisture with irrigation. Coordinate irrigation for cooling, fertilization and pesticide application with routine watering.
- Prevent surface water accumulation in low areas by ditching. Drain surface water if winter flooding occurs.
- Improve drainage through soil profile by subsoiling between beds in spring and fall, particularly in areas where drainage is poor.
- Avoid unnecessary soil compaction. Limit movement of equipment over beds when soil is wet.

SECOND YEAR

Chemical

- In spring, apply metalaxyl to symptomatic areas or high risk areas as early as possible.
- In summer and early fall (June-October) do not apply metalaxyl even if symptoms appear or are noticed. As soil warms and dries throughout the summer and fall, activity of *Phytophthora* decreases. Little benefit will be gained through treatment at this time.
- In winter, do not apply metalaxyl even if infected. The benefit to infected seedlings will be minimal before lifting and progression of the disease is usually halted after outplanting.

Cultural

- Avoid causing excess soil moisture with irrigation. Coordinte irrigation for cooling, fertilization and fungicide treatments with routine watering.
- Roguing symptomatic seedlings is not necessary and will not reduce disease spread in the same season. However, prior to lifting, delineate infection centers. Remove and destroy seedlings in these centers so that badly-infected seedlings are not graded and inadvertently packed. Mapping infection centers may be helpful for reference when planning sowing locations or drainage improvements.
- Improve drainage through soil profile by subsoiling between beds in spring or fall, particularly in areas where drainage is poor.
- Prevent surface water accumulation in low areas by ditching. Drain surface water if winter flooding occurs.

PRIOR TO TRANSPLANTING

Chemical

- Fumigation (e.g. metam-sodium, dazomet, methyl bromide-chloropiorin) may be helpful in nurseries, particularly where *Phytophthora* was present in previous crop.
- Granular formulations of metalaxyl are available which can be incorporated into soil before transplanting. Release of fungicide from granules occurs after irrigation or rain. Application at this time will give some protection but active uptake will be limited until root growth starts.

Cultural

- Ensure adequate drainage by ditching; tiling, etc.
- Subsoil to remove or break up hardpans.
- Provide some slope to actual seedbed areas.
- Use only beds which are higher than the road.
- Avoid transplanting when high soil mositure will cause extensive compaction.
- Avoid transplanting into high-risk areas: chronic wet areas, drainages, bed ends which are lower than road, fields with previous history of *Phytophthora*.
- Avoid transplanting bareroot stock from other nurseries. Use within nursery stock or container stock.
- For spring transplants, transplant as late as is reasonable if trees are infected or from an infected area, or if healthy trees are going into high-risk area.
- If high-risk areas must be planted, use tolerant or resistant species in these areas.
- Seedlings scheduled for transplanting should be graded to remove as many moderately to severely *Phytophthora*-infected seedlings as possible. Moderately or severely infected seedlings often are chlorotic, stunted, or noticeably root-rotted.

TRANSPLANTS

Chemical

- If seedlings are disease-free, do not apply metalaxyl unless planting into high-risk areas. Apply two weeks following transplanting to allow for development of roots capable of absorbing the fungicide.
- If known to be infected prior to transplanting (in seedbed): 1) apply metalaxyl two weeks following transplanting or 2) do not apply metalaxyl if seedlings are graded prior to transplanting (infected seedlings discarded) and graded seedlings transplanted to a "good" site (well-drained, light soil).
- For fall transplants, apply metalaxyl in winter or spring following transplanting if symptoms appear (wait at least two weeks before applying if symptoms are detected during transplanting.)
- For spring transplants, apply metalaxyl in spring if symptomatic (wait at least two weeks before applying if symptoms detected during transplanting).
- In winter, just prior to lifting (for seedlings transplanted for at least one growing season), do not apply metalaxyl even if infected. The benefit to infected seedlings will be minimal before lifting and progression of the disease is usually halted after outplanting.

Cultural

- Avoid causing excess soil moisture with irrigation particularly during transplant establishment. Coordinate irrigation for coolings, frost protection, pesticide application, and fertilization with routine watering.
- Improve drainage through soil profile by subsoiling between beds in spring or fall, particularly in areas where drainage is poor during rainy season.
- Prevent surface water accumulation in low areas by ditching. Drain surface water if winter flooding occurs.
- Avoid unnecessary soil compaction. Limit movement of equipment over beds when soil is wet.
- Roguing symptomatic seedlings is not necessary and will not reduce disease spread in the same season (see also roguing in second year).

LIFTING AND STORAGE

Chemical

- None

Cultural

- Avoid lifting seedlings when soil moisture is so high that most soil cannot be removed from root systems.
- Wash equipment after use in infected fields.
- Destroy seedlings from infected fields which are culled in the packing house.
- Minimize storage time. Freezer storage is best for retarding the development of the disease.
- Remove from beds and destroy those dead and infected seedlings which were not lifted. Do not plow under, particularly if no soil treatment is planned prior to the next crop.

[1/] Resistant = western redcedar
Tolerant = hardwoods, pine, spruce, larch, incense cedar
Highly susceptible = western and mountain hemlock, Douglas-fir, true fir

[2/] High-risk areas are sites where *Phytophthora* was present in the previous crop, low spots, poorly drained areas, or flood-prone areas.

[3/] Treatment with fungicides should be preceded by confirmation of *Phytophthora* spp. by a pathologist.